# QUICK LAB Designing Crumple Zones

**TARGET SKILLS**
- Hypothesizing
- Performing and recording
- Analyzing and interpreting
- Communicating results

How soft is too soft and how rigid is too rigid for an effective vehicle crumple zone? In this lab, you will design and test several materials to determine the optimum conditions for passengers in a vehicle.

Obtain a rigid (preferably metal) toy vehicle to simulate the passenger cell of an automobile. The vehicle must have an open space in the centre for the "passenger." Make a passenger out of putty, modelling clay, or some material that will easily show "injuries" in the form of dents and deformations.

Design and build some type of device that will propel your vehicle rapidly into a solid wall (or stack of bricks) with nearly the same speed in all trials. The wall must be solid, but you will need to ensure that you do not damage the wall. Perform several crash tests with your vehicle and passenger and observe the types of injuries and the extent of injuries caused by the collision.

Select a variety of materials, from very soft to very hard, from which to build crumple zones. For example, you could use very soft foam rubber for the soft material. The thickness of each crumple zone must be approximately one third the length of your vehicle.

One at a time, attach your various crumple zones to your vehicle and test the effectiveness of the material in reducing the severity of injury to the passenger. Be sure that the vehicle travels at the same speed with the crumple zone attached as it did in the original crash tests without a crumple zone. Also, be sure that the materials you use to attach the crumple zones do not influence the performance of the crumple zones. Formulate an hypothesis about the relative effectiveness of each of the various crumple zones that you designed.

## Analyze and Conclude

1. How do the injuries to the passenger that occurred with a very soft crumple zone compare to the injuries in the original crash tests?
2. How do the injuries to the passenger that occurred with a very rigid crumple zone compare to the injuries in the original crash tests?
3. Describe the difference in the passenger's injuries between the original crash tests and the test using the most effective crumple zone material.

## Apply and Extend

4. The optimal crumple zone for a very massive car would be much more rigid than one for a small, lightweight car. However, a crash between a large and a small car would result in much greater damage to the small car. Write a paragraph responding to the question "Should car manufacturers consider other cars on the road when they design their own cars, or should they ignore what might happen to other manufacturers' cars?"
5. Crumple zones are just one of many types of safety systems designed for cars. Should the government regulate the incorporation of safety systems into cars? Give a rationale for your answer.
6. Some safety systems are very costly. Who should absorb the extra cost — the buyer, the manufacturer, or the government? For example, should the government provide a tax break or some other monetary incentive for manufacturers to build or consumers to buy cars with highly effective safety systems? Give a rationale for your answer.

When a rigid car hits a wall, a huge force stops the car almost instantaneously. The car might even look as though it was only slightly damaged. However, parts of the car, such as the steering wheel, windshield, or dashboard, exert an equally large force on the passengers, stopping them exceedingly rapidly and possibly causing very serious injuries.

When a car with well-designed crumple zones hits a wall, the force of the wall on the car causes the front of the car to collapse over a slightly longer time interval than it would in the absence of a crumple zone. Since $\vec{F}\Delta t$ is constant and $\Delta t$ is larger, the average force, $\vec{F}$, is smaller than it would be for a rigid car. Although many other factors must be considered to reduce injury in collisions, the presence of crumple zones has had a significant effect in reducing the severity of injuries in automobile accidents.

The concept of increasing the duration of an impact applies to many forms of safety equipment. For example, the linings of safety helmets are designed to compress relatively slowly. If the lining was extremely soft, it would compress so rapidly that the hard outer layer of the helmet would impact on the head very quickly. If the lining did not compress at all, it would collide with the head over an extremely short time interval and cause serious injury. Each type of sport helmet is designed to compress in a way that compensates for the type of impacts expected in that sport.

**WEB LINK**

***www.mcgrawhill.ca/links/physics12***

To learn more about the design and testing of helmets and other safety equipment in sports, go to the above Internet site and click on **Web Links**.

## 4.1 Section Review

1. K/U Define momentum qualitatively and quantitatively.

2. K/U What assumption do you have to make in order to show that the two forms of Newton's second law ($\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$ and $\vec{F} = m\vec{a}$) are equivalent?

3. I Try to imagine a situation in which the form $\vec{F} = m\vec{a}$ would not apply, but the form $\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$ could be used. Describe that situation. How could you test your prediction?

4. C State the impulse-momentum theorem and give one example of its use.

5. MC A bungee jumper jumps from a very high tower with bungee cords attached to his ankles. As he reaches the end of the bungee cord, it begins to stretch. The cord stretches for a relatively long period of time and then it recoils, pulling him back up. After several bounces, he dangles unhurt from the bungee cord (if he carried out the jump with all of the proper safety precautions). If he jumped from the same point with an ordinary rope attached to his ankles, he would be very severely injured. Use the concept of impulse to explain the difference in the results of a jump using a proper bungee cord and a jump using an ordinary rope.

**UNIT PROJECT PREP**

Can environmentally responsible transportation be the product of properly applying scientific models and theories?

- Is the theory of momentum and impulse currently used in vehicle design?
- Can you envision using momentum and impulse theory to design more environmentally responsible transportation systems?